Amendments to the Drawings:

Please substitute the attached sheet (Figs. 25A and 24B) for the drawing originally filed with the application. Figs. 25A and 25B have been amended to include a "Prior Art" caption.

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REMARKS

Claims 1-17 are pending. Claims 5-12 have been withdrawn. Claims 18-20 have been added. Support for claims 18 and 19 is found in paragraphs 00082, which discloses an impurity concentration for the isolation region of 1.2×10^{19} cm^{-3} and paragraph 0093, which discloses an impurity concentration for the collector layer of 1×10^{17} cm^{-3}, which is less than the impurity concentration of the isolation region. Support for claim 20 is found in paragraph 0028. A detailed listing of all claims that are, or were, in the application, irrespective of whether the claim(s) remain under examination in the application, is presented, with an appropriate defined status identifier. The specification has been amended to reformat some of the impurity concentrations and dosages. Applicant respectfully requests that the foregoing amendments be made prior to further examination of the present application, and respectfully requests reconsideration of the present application in view of the foregoing amendments and the reasons that follow.

The examiner indicates that claims 5-17 are withdrawn from consideration, and claims 6-12 have been cancelled. Claims 13-17 are method claims and are properly examined in the present application once allowable subject matter has been found for the product claims, under the doctrine set forth in *In re Ochiai*. Accordingly, these claims remain in the case.

Figures 24A and 24B have been amended to include a "prior art" designation.

Claims 1 and 2 are rejected under Section 103(a) based on the device shown in Figures 24A and 24B. The examiner urges that it would have been obvious to control W to a value greater than a thickness d, in which the distance W is a distance from an outermost position of an portion of the emitter electrode, the portion being in contact with the base layer, to an innermost position of the isolation region, and the thickness d is a dimension in a depth direction of the drift layer. He urges that this was merely the determination of an optimum or working range that involved only routine skill in the art, citing *In re Aller*, 105 USPQ 233.

However, it is well settled that a particular parameter must first be recognized as a result-effective variable, *i.e.*, a variable which achieves a recognized result, before the determination of the optimum or workable ranges of said variable might be characterized as routine experimentation. MPEP 2144.05 citing *In re Antonie*, 559 F.2d 618, 195 USPQ 6 (CCPA 1977) (The claimed wastewater treatment device had a tank volume to contractor area of 0.12 gal./sq. ft. The prior art

did not recognize that treatment capacity is a function of the tank volume to contractor ratio, and therefore the parameter optimized was not recognized in the art to be a result- effective variable.) and *In re Boesch*, 617 F.2d 272, 205 USPQ 215 (CCPA 1980) (prior art suggested proportional balancing to achieve desired results in the formation of an alloy). There is nothing in the record which suggests that W is a result-effective variable, and therefore the rejection based on Figures 24A and 24B is not supportable. It was applicants who discovered that diode operation performance of the IGBT disclosed in Japanese Unexamined Patent Application Publication No.2002-353454 cited above is not improved even if the rear collector layer is made low injection because holes are also injected from the heavily doped p+ isolation region in the diode operation, and that, therefore, a structure is needed that suppresses hole injection from the p+ isolation layer (see paragraph 0012). In order to solve the problem, applicants discovered that d should be less than W.

Figures 24A and 24B are sectional views of a part of a reverse blocking IGBT. Figure 24(a) shows the cross section when a reverse voltage is applied and Figure 24(b) shows the cross section when a forward voltage is applied. In Figures 24(a) and (b), a deep p+ type isolation region 11 is formed by diffusion from front and rear surfaces of an n type FZ wafer that serves as an n- drift layer 3. Then, MOS gate structures are formed comprising a plurality of p+ base layers selectively formed in the front surface region of the n- drift layer 3, n+ emitter region 5 selectively formed in the surface region of each of the p+ base layers 4, gate oxide films 6, gate electrodes 7, and an emitter electrode 8. After the formation of the MOS gate structure, a thickness of the n- type drift layer 3 is reduced to about 100 µm in the case of reverse withstand voltage of 600 V by removing the rear portion of the drift layer. After the thickness reduction, a p+ collector layer 9 is formed by ion implantation from the rear surface and following annealing. The resulting IGBT device is surrounded by the heavily doped p+ isolation region 11 around the side face of the device at the dicing position 10. Consequently, a depletion layer 12 on application of a reverse voltage only extends towards the vicinity of the pn junction at the p+ collector layer 9 and the p+ isolation region 11 and does not appear at the side face of the device at the dicing position. Thus, an electric field develops only on the front surface of the device. Such a device is disclosed, for example, in Japanese Unexamined Patent Application Publication Nos. H07-307469, 2001-185727, 2002-076017, and 2002-353454 and M. Takei *et al.*, Proceedings of 2001 International Symposium on Power Semiconductor Devices and ICs, 2001, Osaka, Japan, pages 413-416, "600 V-IGBT with Reverse Blocking Capability". If a conventional IGBT that lacks this p+ isolation region 11 is

reversely biased with an emitter at a ground potential and a collector at a negative potential, electric field concentration occurs at a substrate end region of a p+ collector layer, resulting in increased leakage current and insufficient reverse breakdown voltage.

Antiparallel connection as in Figure 25(c) of the devices of Figures 24(a) and (b) make it possible to control forward and reverse current and to withstand application of forward and reverse voltages. Thus, the device of Figures 24(a) and (b) can be operated as a bidirectional device. Application of such bidirectional devices to an ac to ac converter allows direct conversion from ac to ac. Size of a converter circuit is drastically reduced as compared with a converter consisting of a converter, a capacitor, and an inverter. Consequently, the cost is substantially reduced. The bidirectional device operates as an IGBT and a free wheeling diode (FWD).

At the time of reverse recovery in the FWD operation, accumulated excess carriers are swept out by a depletion layer extending from the collector side. If the quantity of the carriers in the collector side is large, reverse recovery peak current becomes large, which is hard recovery behavior. For a reverse blocking IGBT to use as a FWD, improvement of the reverse recovery performance is essential.

It has been revealed that diode operation performance of the IGBTs such as those disclosed in Japanese Unexamined Patent Application Publication No.2002-353454 and exemplified in Figures 24A and 24B is not improved even if the rear collector layer is made low injection because holes are also injected from the heavily doped p+ isolation region in the diode operation. Therefore, a structure is needed that suppresses hole injection from the p+ isolation layer.

Moreover, leakage current in the reverse biased condition, in which the emitter is positive and the collector is negative as shown in Figure 24(a), depends on emitter injection efficiency, which is a parameter to determine an open base amplification factor of the pnp transistor. The emitter injection efficiency is substantially determined by a p+ layer (not shown in Figures 24(a) and (b)) formed in the surface region in the p+ base layer between n+ emitter regions 5,5, the p+ layer being in contact with the emitter electrode. The p+ layer is deeper than n+ emitter region 5 and shallower than p+ base layer 4, and is doped more heavily than p+ base layer 4. Since the p+ layer is extremely heavily doped, in an amount which can be more than 1×10^{19} cm^{-3}, in order to prevent latch-up, emitter injection efficiency may be higher than 0.9. As a result, the leakage current at high temperature is more than 10 mA/cm^2, which is about 100 times greater than is typical. The emitter

injection efficiency can be decreased by forming an n+ layer doped more heavily than n- drift layer 3 under p+ base layer 4. The n+ layer has a depth covering p+ base layer 4 in the case of a planar type, while the n+ layer is disposed between p+ base layer 4 and n- drift layer 3 in the case of a trench type. The n+ layer in the case of the planar type, however, produces a rigorous decrease in electric field intensity during off-operation, deteriorating blocking performance. Therefore, a means is needed that reduces the reverse leakage current more readily.

Since thickness of an oxide film that is a diffusion mask for forming a p+ isolation region is not great enough according to conventional technology, boron atoms eventually penetrate through the oxide film in high temperature diffusion around 1,250°C forming a p+ layer even under the oxide film. This situation hinders formation of a normal MOS structure and an abnormal chip of IGBT may be formed that will not turn-on. All of this is described in applicant's specification, at paragraphs 0005, 0006, 0007, 0012, 0013 and 0014. There is nothing to suggest the solution that is proposed in claim 1 to the problems displayed by prior art devices. No *prima facie* case of obviousness exists.

Claim 3 is rejected under Section 103(a) based on the device shown in Figures 24A and 24B in view of Ogura *et al.* (US 5,463,231). Claim 4 is rejected under Section 103(a) based on the device shown in Figures 24A and 24B in view of Akiyama *et al.* (JP 3-48462). Neither Ogura *et al.* nor Akiyama *et al.* suggest how to improve the performance of the device shown in Figures 24A and 24B, and thus do not overcome the failings discussed above with respect to the rejection of claim 1.

Claim 20, newly added, recites that the ambipolar diffusion length La is less than W. As described in paragraph 0028, "when the distance between the isolation region and the active region is longer than an ambipolar diffusion length of the minority carriers, that are holes, the concentration of the holes injected from the isolation region decays rapidly enough. Therefore, hole injection from the isolation region can be ignored in this case." Paragraph 0074 further describes that "in the case lifetime is decreased, the reverse recovery peak current is further reduced in comparison with the case of non-killer, in which the lifetime is not decreased. In Figure 2, the ambipolar diffusion length La1 = 194 μm in the case of non-killer, while the ambipolar diffusion length La2 = 82 μm in the case an electron beam of 4 Mrad (=40 kGy) is irradiated. The thickness d of the n- drift layer is about 100 μm. The electron beam irradiation decreased the reverse recovery current." By ensuring that La < W, the concentration of the holes injected from the isolation region can decay rapidly enough and the peak reverse recovery current can be decreased. The advantages of La < W is not suggested in the cited documents.

Applicant believes that the present application is now in condition for allowance. Favorable reconsideration of the application as amended is respectfully requested. The Examiner is invited to contact the undersigned by telephone if it is felt that a telephone interview would advance the prosecution of the present application.

If there are any problems with this response, Applicant's attorney would appreciate a telephone call. In view of the foregoing, it is believed none of the references, taken singly or in combination, disclose the claimed invention. Accordingly, this application is believed to be in condition for allowance, the notice of which is respectfully requested.

Respectfully submitted,

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